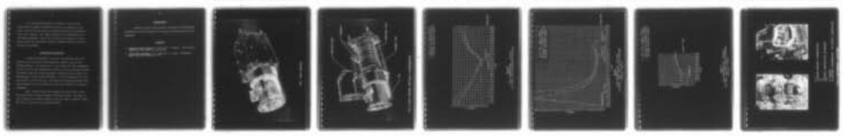
AD-A076 186 BATTELLE MEMORIAL INST COLUMBUS OHIO COLUMBUS LABS F/G 13/1
EXPERIMENTAL DETERMINATION OF HEAT REQUIREMENTS FOR THE MARK I --ETC(U)
SEP 69 P S RIEGEL, J S GLASGOW N00014-66-C-0199

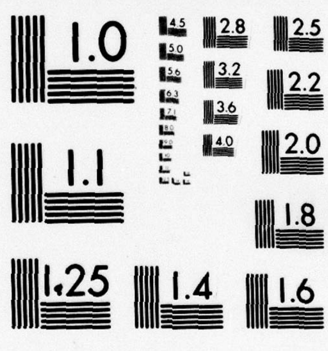
UNCLASSIFIED NL

| OF |

ADA 076186



END
DATE
FILMED
12-79
DDC



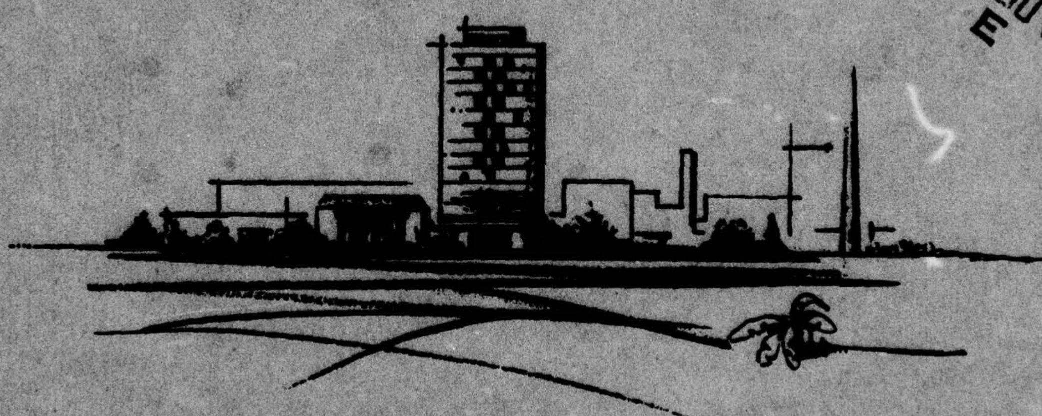
MICROCOPY RESOLUTION TEST CHART

Rettini 485
(00652)

LEVEL

AD A076186

RESEARCH REPORT



APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

BATTELLE MEMORIAL INSTITUTE

COLUMBUS LABORATORIES

79 11 06 065

79 05 02 041

THE COLUMBUS LABORATORIES of Battelle Memorial Institute comprise the original research center of an international organization devoted to research.

The Institute is frequently described as a "bridge" between science and industry – a role it has performed in more than 90 countries. As an independent research institute, it conducts research encompassing virtually all facets of science and its application. It also undertakes programs in fundamental research and education.

Battelle-Columbus – with its staff of 3,000 – serves industry and government through contract research. It pursues:

- research embracing the physical and life sciences, engineering, and selected social sciences
- design and development of materials, products, processes, and systems
- information analysis, socioeconomic and technical economic studies, and management planning research.

505 KING AVENUE • COLUMBUS, OHIO 43201

9 Research rept.,

1

6 [redacted]

[redacted]

EXPERIMENTAL DETERMINATION OF HEAT REQUIREMENTS
FOR THE MARK I PTC

to

SUPERVISOR OF DIVING
U. S. NAVY

[redacted] N00014-66-C-0199 15

September 8, 1969

11 8 Sep 69

12 27

10
by
P. S. Riegel [redacted] J. S. Glasgow

BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Battelle Memorial Institute · COLUMBUS LABORATORIES

505 KING AVENUE COLUMBUS, OHIO 43201 · AREA CODE 614, TELEPHONE 299-3151 · CABLE ADDRESS: BATMIN

September 8, 1969

LCDR James Majendie, RN
Experimental Diving Unit
Washington Navy Yard
Washington, D. C. 20390

Dear LCDR Majendie:

We enclose with this letter twenty copies of our report "Experimental Determination of Heat Requirements for the Mark I PTC".

You will note that the heat requirements are lower than those which we presented as preliminary data in the meeting of August 28. The preliminary data did not account for the "squeeze" of the mercury thermometers, which caused slightly high readings under pressure. The corrected values agree, in general, with the ranges of values determined analytically by participants in the meeting.

Once the PTC has been insulated we recommend a repeat of the test to establish firm heat requirements for the PTC as insulated.

It was our great pleasure to have the opportunity to work with you on this task, and we hope that the information presented is helpful.

Accession For	
NTIS GRA&I	✓
DDC TAB	
Unannounced	
Justification	
By	
Distribution/	
Availability Codes	
Dist.	Avail and/or special
A	

Sincerely yours,

Jim

J. S. Glasgow
Associate Chief
Equipment Engineering
Research Division

Pete

P. S. Riegel
Research Engineer
Equipment Engineering
Research Division

JSG:PSR/mm
Enc.

EXPERIMENTAL DETERMINATION OF HEAT REQUIREMENTS FOR THE MARK I PTC

INTRODUCTION

The problem of keeping a diver warm in a Personnel Transfer Capsule (PTC) is a fairly new one, for it is only in recent years that PTC's, and the deep-diving systems they serve, have existed. Major attention was attracted to the problem when reports of the death of Berry Cannon were made public. Extreme discomfort due to the cold PTC environment was reported by participants, and the cold, it is conjectured, could have contributed to Mr. Cannon's death. Construction of the Mark I Deep Dive System was nearly complete at the time of the Sealab accident, and up until that time cold was not considered to be a very great problem. However, it suddenly became one.

Civilian diving systems place primary emphasis on successful operation, consistent with reasonable safety and comfort. Conversely, military operations put a higher premium on safety because of the great amount of publicity and criticism directed toward military accident situations versus comparable civilian ones. Thus, while some civilian diving systems work without PTC heat, no military one may do so.

Battelle's involvement in this field began on August 7, of this year when LCdr. Majendie of EDU requested that we investigate the problem. Various analytical techniques were considered but, due to the complexity of the PTC as a heat-transfer mechanism, it was felt that none would yield sufficient accuracy to truly define the magnitude of the heat requirements. Accordingly, an on-site test of the actual PTC was decided to be the best approach.

PURPOSE

The purpose of the test program was to establish the amount of heat required to maintain the interior of the Mark I PTC at a comfortable level for divers.

RESULTS

The test showed that for a condition of moderate forced convection at 810 feet equivalent internal pressure, a heat input of 1620 B/hr (0.48 kw) is required for each degree of temperature differential that is to be maintained between the interior of the PTC and the outside seawater. Thus, if an interior temperature of 90 F is desired in 40 F water, this would require a total heat input of 81,000 B/hr (24 kw).

These results are valid only for a condition of forced convection similar to the test situation. Although the heat requirement seems quite high, it is only equivalent to the air-conditioning load in a modern automobile.

CONCLUSIONS

1. The power required to adequately heat the PTC is far in excess of that available in the PTC.
2. Even with insulation, heating will probably be less than optimum.
3. A PTC heater should be built, sized to use every bit of available power.

4. Realistic heating and cooling requirements should be established, base on complete operational sequences in the most severe possible environments. There are no standards at present.

RECOMMENDATIONS

1. The PTC should be insulated to the greatest practical extent.
2. Heat loss experiments, similar to those described in this report, should be conducted to determine heat requirements after the PTC is insulated.

PROCEDURE

To measure the heat requirements of the Mark I PTC, two avenues of approach were considered. The first was to allow the PTC to come to equilibrium at one temperature, then to immerse it in water at a different temperature and record the time-temperature relationship. The second was to place a heat source within the PTC and record the steady-state value of PTC internal temperature with the heat on and again with the heat off.

Data were taken to permit calculation of heat requirements by either method. However, instrument lag and the presence of the control panel and other equipment within the PTC rendered the transient data nearly worthless for calculation, because of the unknown thermal inertia characteristics of these internal masses.

Data were obtained by mechanically driven, bimetallic element recording thermometers located at diametrally opposite positions in the PTC with one at the suction to the heat source fan. Mercury thermometers were located at convenient viewports where they could be read by divers when the PTC was immersed. Multiple layers of cloth were used to insulate these thermometers from contact with metal, and efforts were made to assure that these thermometers would respond to the gas temperature and not that of the colder metal.

A heat source, constructed at Battelle, was connected to the three electric diver suit heater outlets and located on the interior annular deck plate. The heat source consisted of a circulating fan and a circulating fan and a resistance coil located in an insulated duct. It is shown in Figures 1 and 2.

At the beginning of each run the clock drives on the recording thermometers were started. The PTC was then sealed and the required internal gas pressure applied. The PTC was then lowered over the side until its top was about 2-3 feet under water. A diver then swam around the PTC, reading the internal gas temperature thermometers at the viewports, and an externally located mercury water temperature thermometer.

When, in the judgment of the investigators, the temperature had stabilized, the main circuit breaker in the PTC power supply was turned on, activating the heat source. The temperature rise was reported by the diver, and the test was concluded when temperature had once again reached a steady-state value.

CALCULATION OF HEAT REQUIREMENT

Calculation of heat requirement is based on the following data:

	Surface	410 ft.	810 ft.
Gas	Air	96% He-4% Air	96% He-4% Air
Water Temp., F	64	64	64
Heated PTC Temp., F	72	68.2	67.4
Heat Input, W	1620	1620	1620

For the 810-ft. depth equivalent internal gas pressure,

$$\text{Heat req'd} = \frac{1620\ \text{W}}{(67.4-64)\ \text{F}} = 476\ \frac{\text{W}}{\text{F}} = 1620\ \frac{\text{B}}{\text{hr. - F}}$$

or, for every degree that the PTC is to be maintained above sea temperature, 476 watts of power is required. Thus, if we wish to heat the PTC to 90 F in 40 F water, the total power required is 24 kw or 81,000 B/hr.

Similarly, at 410 feet equivalent internal gas pressure,

$$\text{Heat req'd} = 386\ \frac{\text{W}}{\text{F}} = 1320\ \frac{\text{B}}{\text{hr. - F}}$$

and at the surface,

$$\text{Heat req'd} = 202\ \frac{\text{W}}{\text{F}} = 690\ \frac{\text{B}}{\text{hr. - F}}$$

APPARATUS AND INSTRUMENTATION

Recording thermometers:

1 - Bacharach 40-100 F bimetallic, with 4-hr. drive

1 - Bacharach 60-90 F bimetallic, with 4-hr. drive, recalibrated to read 50-80 F

Internal gas temperature mercury thermometers:

Thermometer Corporation of America #430850Y, -31 to 124 F

Outside water temperature mercury themometer:

Thermometer Corporation of America #430850Y, -31 to 124 F

Heat Source: (See Figures 1 and 2)

240 cfm rated air flow, @ 1 atm

1620 watts @ 27.5 VDC

Locations of instrumentation are shown in Figure 6.

DISCUSSION OF DATA AND RESULTS

Figures 3, 4, and 5 show plots of time versus temperature for the three tests. Temperatures obtained from the mercury thermometers located at the ports are considered to be more reliable than those from the bimetallic recorders, so the averages of the values obtained from the mercury thermometers are used in calculations. At the time of the test, it was known that the inside mercury thermometers were compressed by the gas pressure and were indicating erroneously high temperatures. These have since been calibrated for a pressure in a hyperbaric chamber, and corrected values are plotted on the time versus temperature curves.

The figures given for heat input are about half the preliminary values given orally in the meeting on PTC heating held at NCEL on August 28. The temperature rise used in the preliminary calculation was the difference between the lowest temperature obtained before the heater was turned on and the apparent stabilization temperature with the heater running. However, subsequent calibration of the thermometers at Battelle showed that the PTC had not, in actuality, come to final thermal equilibrium when the heater was turned on. The figures presented herein are based on the difference between seawater temperature and steady-state PTC interior temperature with the heater running. Of greatest interest are the figures obtained at 810 feet equivalent gas pressure, since heat transfer will be most severe (or at least <u>not less</u> severe) at this pressure.

In free convective heat transfer, the inside film coefficient varies with a power of the product of the Grashof and Prandtl numbers, while in forced convection it varies with the product of a power of the Reynolds number and a power of the Prandtl number. While the aforementioned parameters are of great help in situations involving common geometries (flat surfaces, cylinders, tubes and the like), their application to complicated geometries must be viewed with caution. The three separate tests that were conducted can, indeed, be made to fit a theoretical mold, but not very tightly.

A number of simplified mathematical models may be substituted for the actual case. One such model is an empty hollow sphere of uniform wall thickness under a condition of free convection. Another is a flat plate having the same area as the inside of the sphere, and which has gas moving

along it at a representative velocity. The imaginative analyst can conjure up more if he desires. The *important thing is that* there exists no known purely analytical method for predicting the thermal behavior of the Mark I PTC with accuracy of, say $\pm$ 10%.

Estimates based on simplifying assumptions are useful, however, for predicting order-of-magnitude values. The implausibly high value of such early estimates led to the development of this experimental program to find out whether such estimates were reasonable. Unfortunately, they were.

The results of these tests should be reasonably applicable to the design of a PTC heater if a circulating fan of about the same capacity as the one used in the experiment is used. It is desirable to create in the PTC as uniform a temperature as possible. Because of the huge heat loss at the wall, it is necessary to provide a high degree of mixing to keep the gas temperature reasonably uniform, unless the heat source is uniformly distributed around the inside of the shell. These test results will predict the heat loss under similar conditions of forced convection. An "electric blanket" lining the inside of the PTC would be better described by an analytical approach to obtain heat loss information, since the preliminary mode of heat transfer, in this case, would be free convection, and since the losses between the blanket and the shell may be reasonably predicted by classical theory.

Since, in forced convection, film coefficient is independent of temperature difference, little error may be expected in scaling up the relatively small 3.4 F rise of the test to the desired 50 F or 60 F rise demanded by operating conditions.

It is theoretically possible to establish a value for free convective heat transfer by analyzing the time versus temperature decay curve. This was not done because an instantaneous time versus temperature curve was not obtained. The thermal capacity of the thermometers and of the interior equipment in the PTC was so enormous in comparison to that of the gas itself that this method, although it appeared initially attractive, proved to be unworkable.

MISCELLANEOUS OBSERVATIONS

It might be appropriate to note that the submerged condition of the PTC may not be the most severe operational condition from the diver heating standpoint. The internal gas is cooled drastically upon decompression (to 59 F from 67 F upon decompression from 810 to 410 feet equivalent pressure), and during a large part of the decompression schedule the PTC is mated to the DDC and exposed to the surface environment. This could range from -40 F with wind to 60 kt. to +130 F and calm. The heating and cooling requirements under these conditions can not be predicted from the data collected in the reported experiments.

Also, the Mark I divers have commented that they noticed a chill when the PTC hatch is opened to expose a free water surface. The reason for such a response is not known, although it could be caused by humidity, radiant heat loss, or some other heat transfer phenomena.

ACKNOWLEDGMENT

We wish to thank all the personnel of the Mark I Deep Dive System The USNS Gear, and FMC Corporation who assisted us during the course of the experiment.

REFERENCES

1. Elements of Heat Transfer by M. Jakob and G. A. Hawkins. Third Edition, John Wiley & Sons, New York, April, 1958.

2. Compact Heat Exchangers by W. M. Kamp and A. L. London. The National Press, Palo Alto, California, 1955.

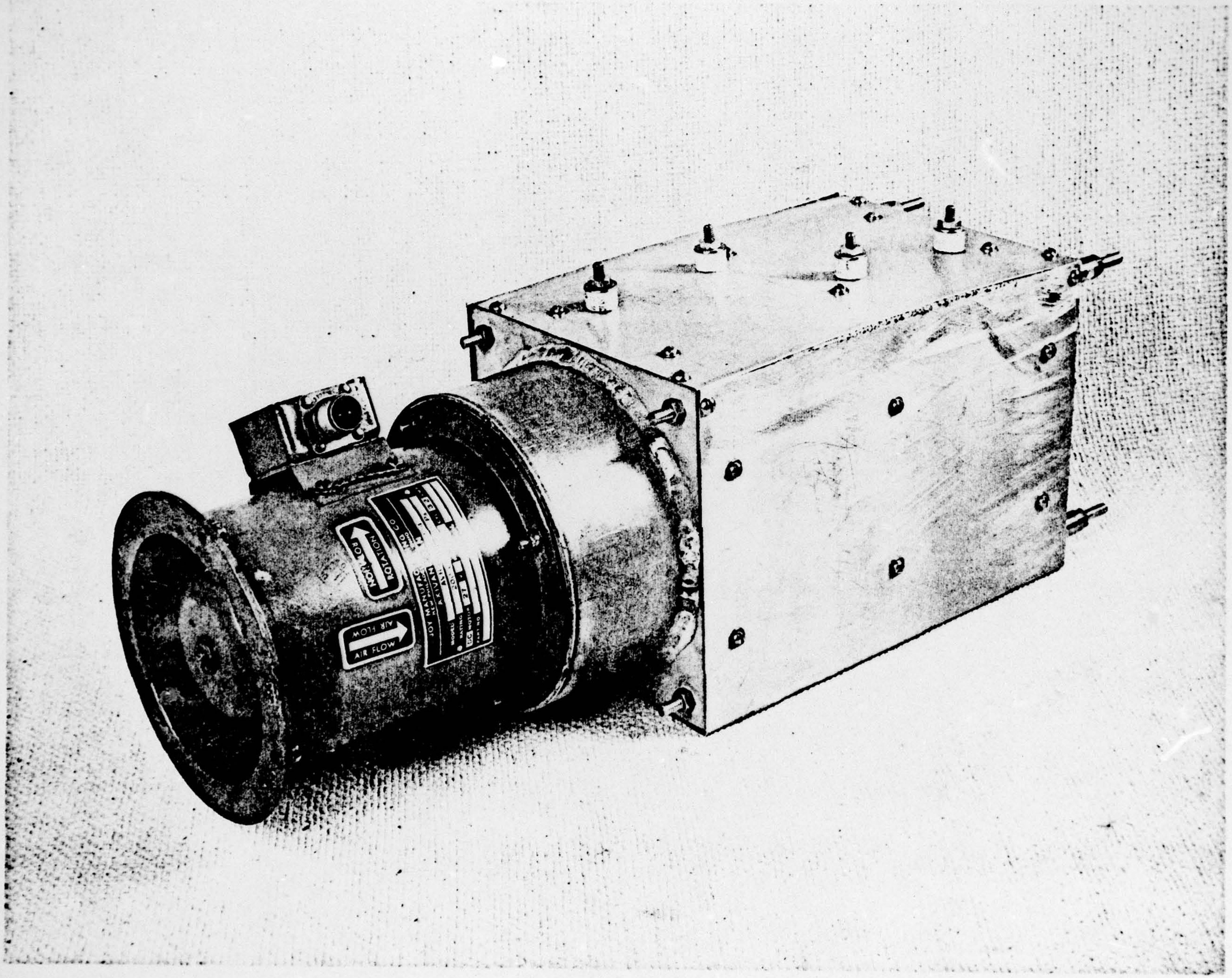


FIG. I HEAT SOURCE

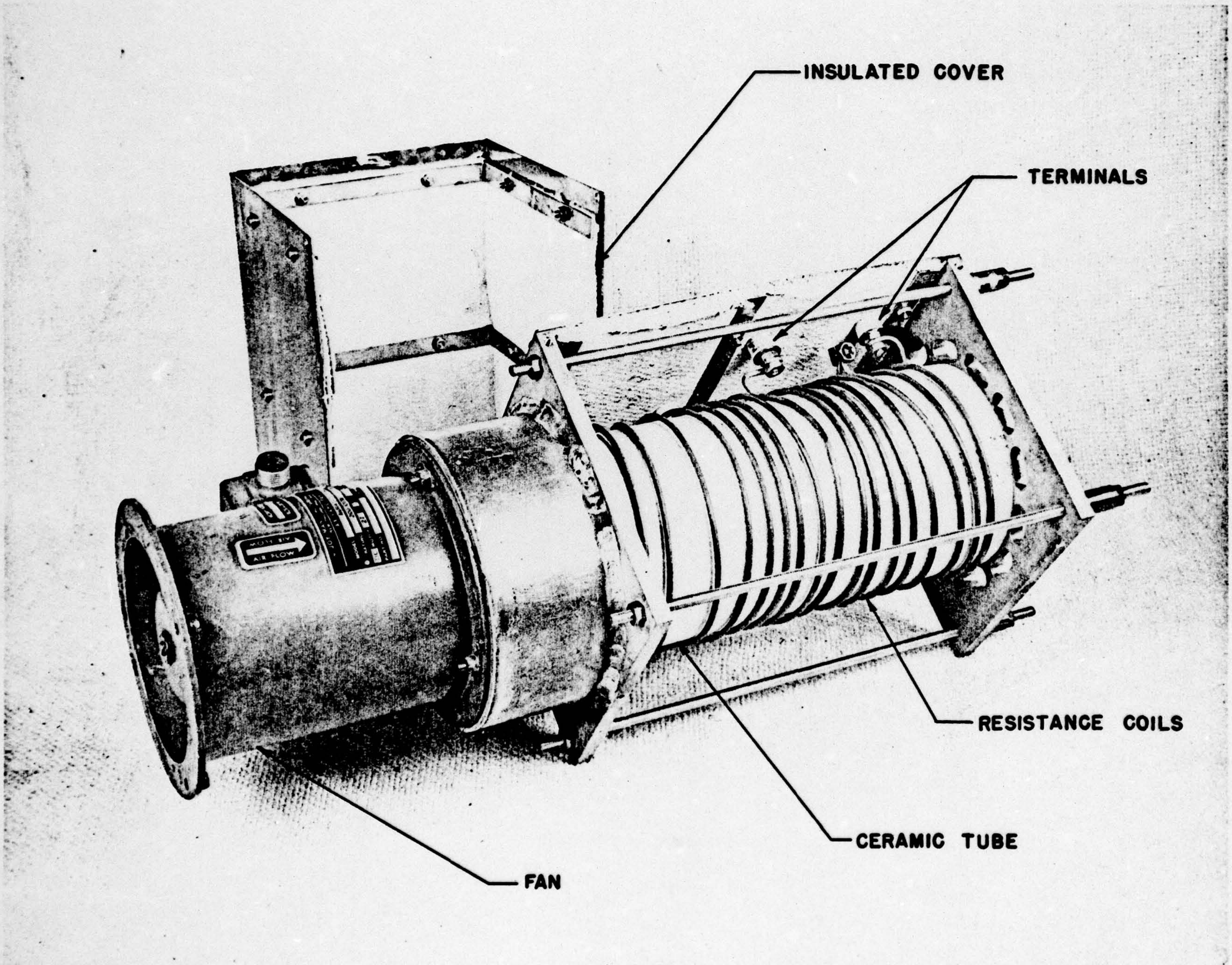


FIG. 2 HEAT SOURCE PARTIALLY DISASSEMBLED

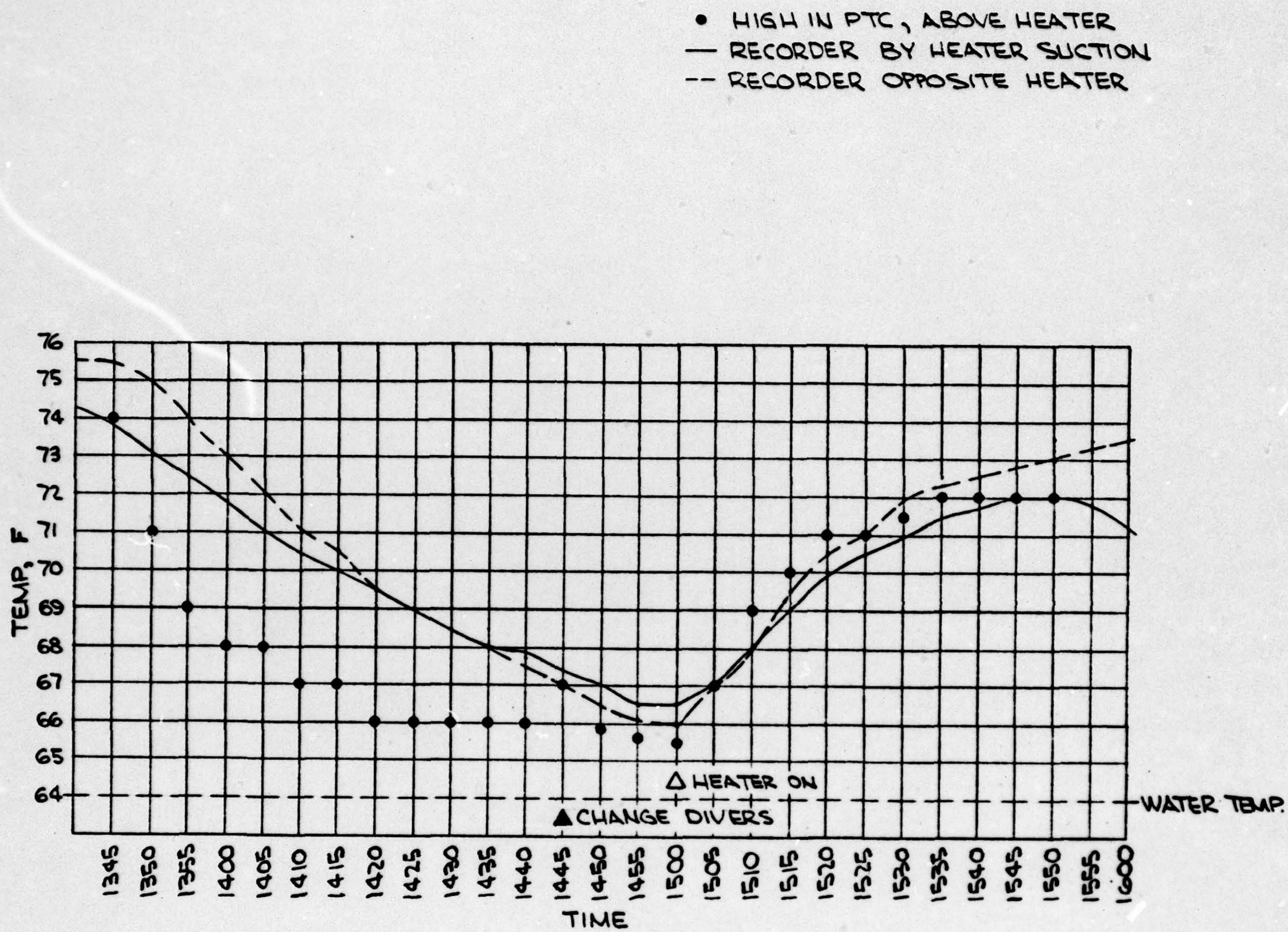


FIG. 3

TIME-TEMPERATURE 8-26-69

PTC TEST - AIR AT ATMOSPHERIC PRESSURE

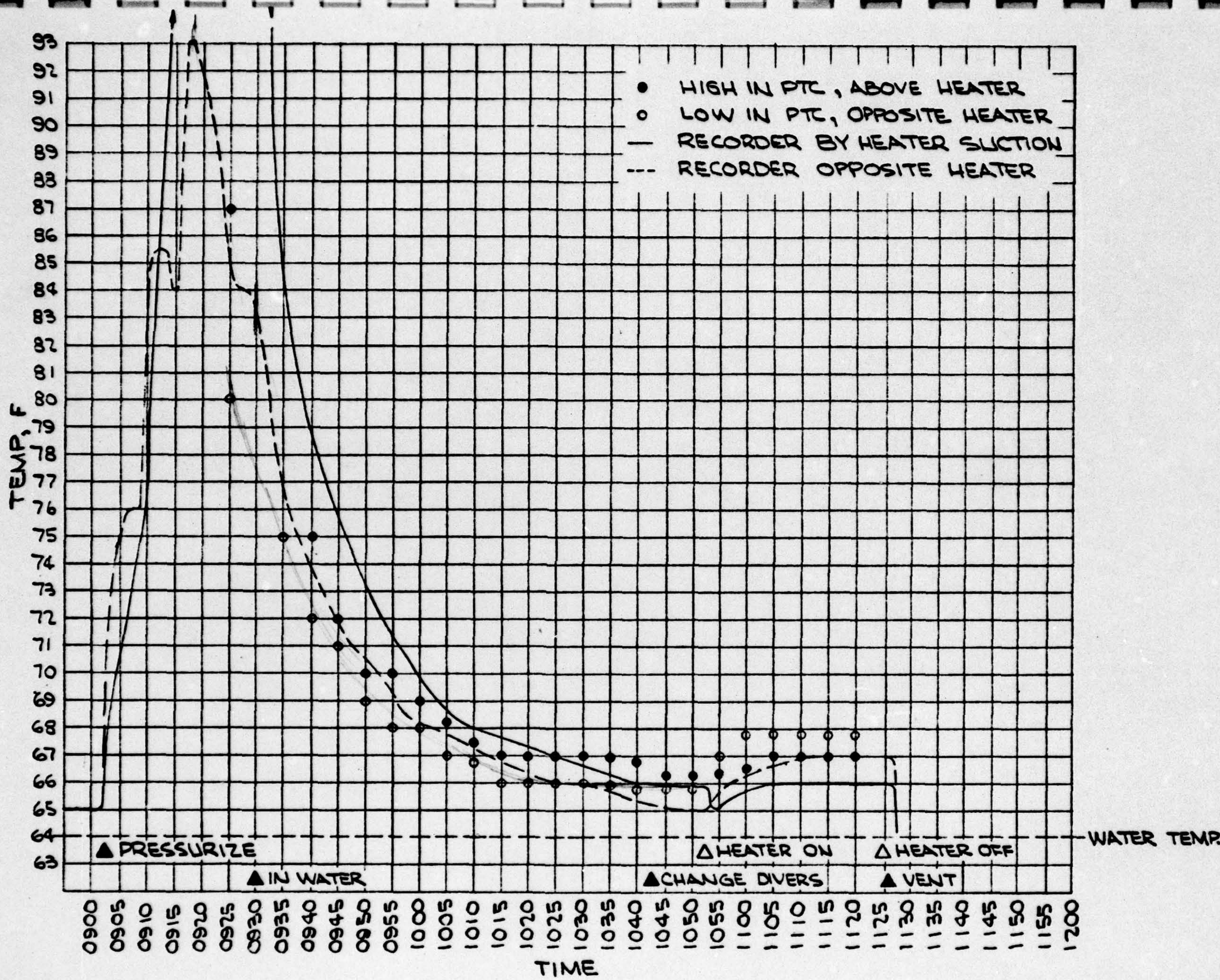


FIG. 4

TIME-TEMPERATURE 8-27-69

PTC TEST - 810' SEA WATER PRESSURE

96% He - 4% Air

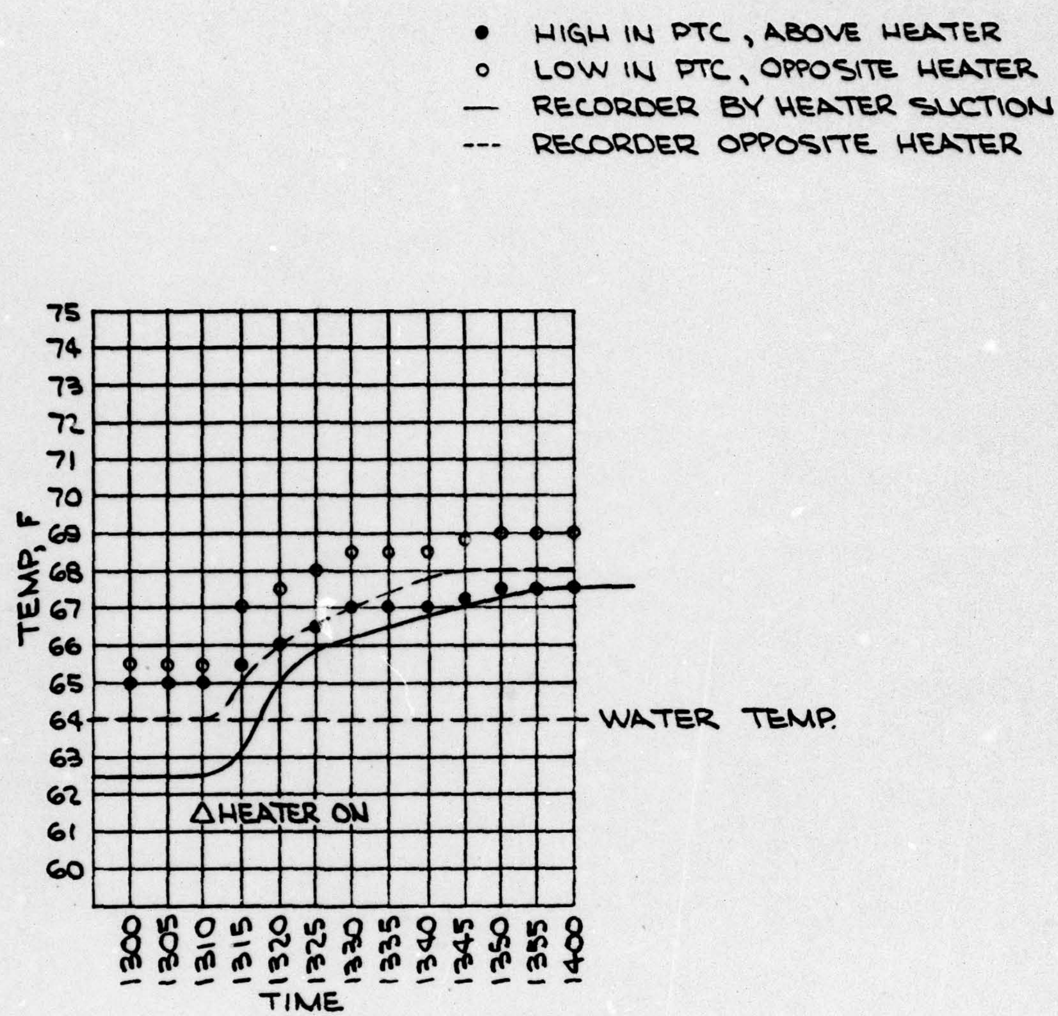
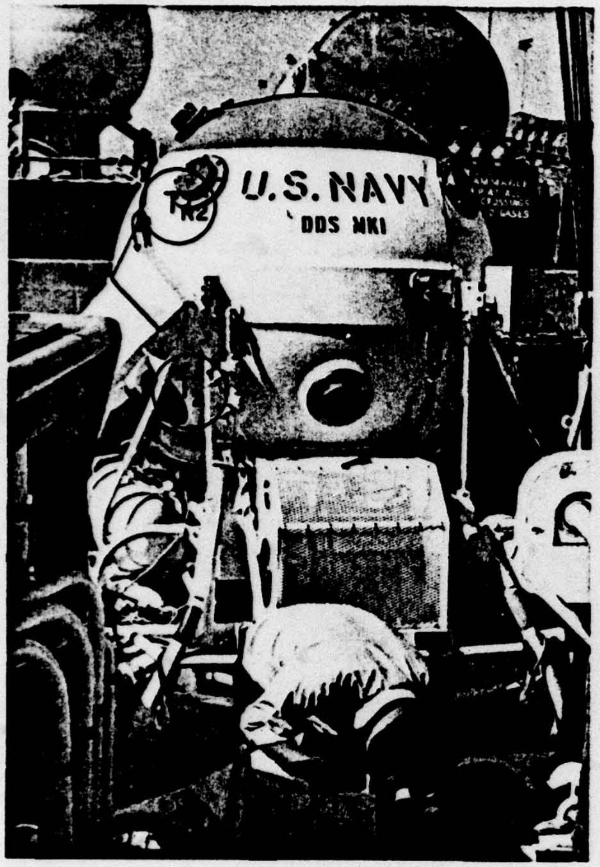


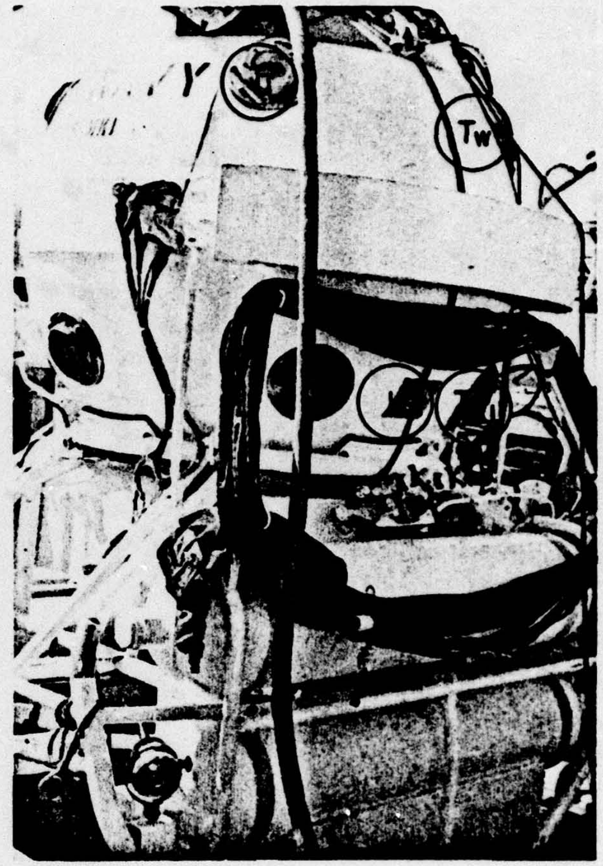
FIG. 5

TIME-TEMPERATURE 8-27-69

PTC TEST - 410' SEA WATER PRESSURE

96% He - 4% Air





T_1, T_2 — INSIDE MERCURY THERMOMETERS

T_{R1}, T_{R2} — INSIDE TEMPERATURE RECORDERS

H— HEATER

T_W— OUTSIDE THERMOMETER FOR WATER TEMPERATURE

FIG. 6 INSTRUMENT LOCATIONS